

Carbon-Smart 4-in-1 Slab: TO,PT,LC3 and UHPFRC

Topology-Optimized ■ Post-Tensioned ■
Eco-UHPFRC/LC3 Hybrid Floor System

Presented by

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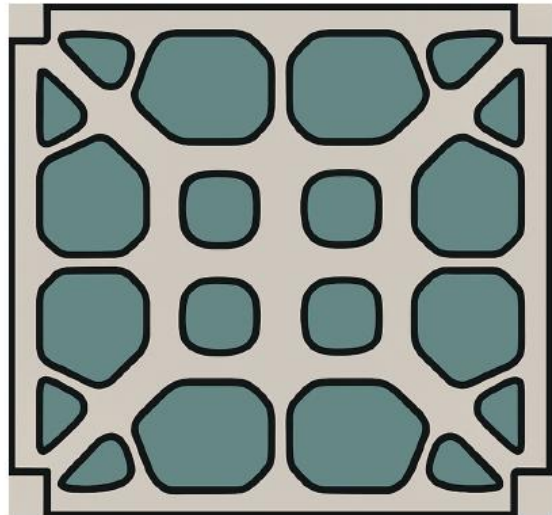
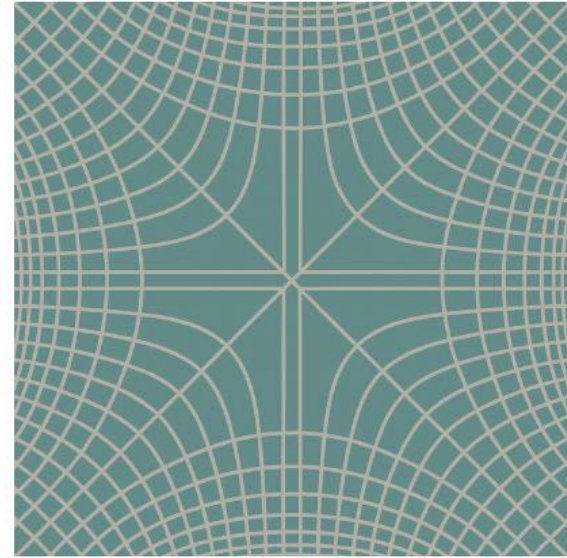
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Carbon-Smart Rib Tendon EcoSkin™ Floor

A productised slab concept:

lighter ■ **lower-carbon** ■ **faster to build**



Serviceability in-loop

Manufacturable ribs

Audit-ready outputs

Pitch in one line: Make the slab follow the optimized flow *and* the carbon budget: an extrudable topology-optimised rib network, upgraded with tendon “highways” and a thin eco-UHPFRC topping.

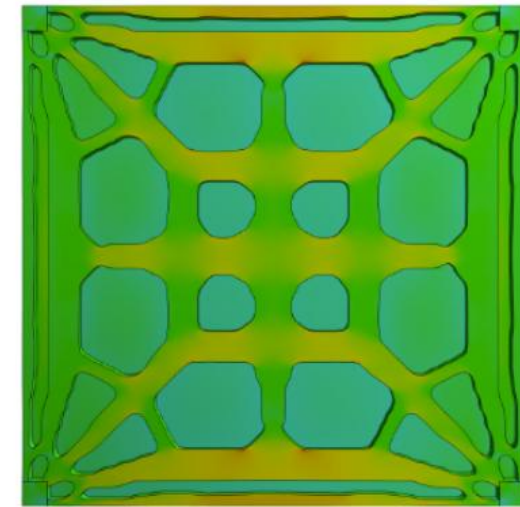
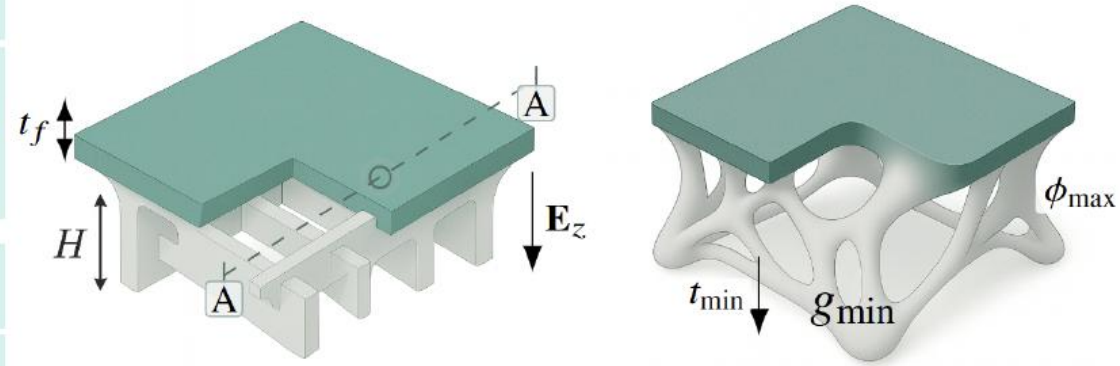
From “draw ribs then check later” to **constraints + deliverables.**

Keywords

Topology optimisation ■ Serviceability
■ UHPFRC ■ Post-tensioning ■ LC3

Abstract / motivation

- ▶ Slabs repeat: big mass & big embodied CO₂.
- ▶ Reality: **SLS (deflection/cracking)** + **buildability** control the design.
- ▶ So we enforce SLS probes + manufacturability *inside* the optimiser.
- ▶ Then we “upgrade the winners”: **PT** + **eco-UHPFRC** + **LC3 ribs**.
- ▶ Output: code-checkable layout + carbon dashboard vs deflection-matched baselines.



Buildability grammar: min rib thickness / min gap / max solid zone.

System architecture

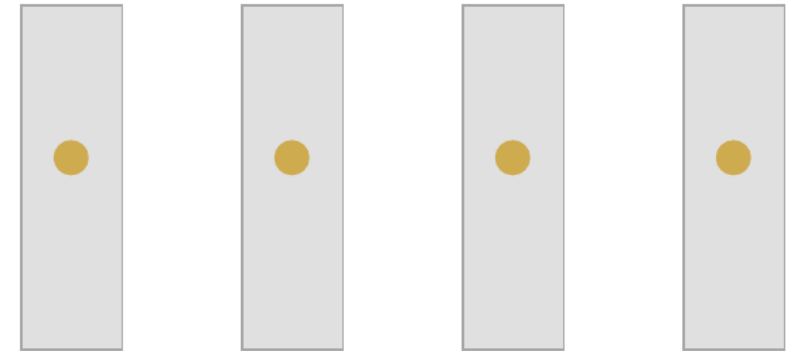
- ▶ **Topology:** MC-Extruded rib network (*straight ribs = reusable formwork*).
- ▶ **Prestress:** tendons routed along main ribs (*“tendon highways”*), targeting SLS.
- ▶ **Materials:** **LC3** in ribs (bulk volume) + **eco-UHPFRC** topping (thin, durable).

Why this combo wins (3 lenses)

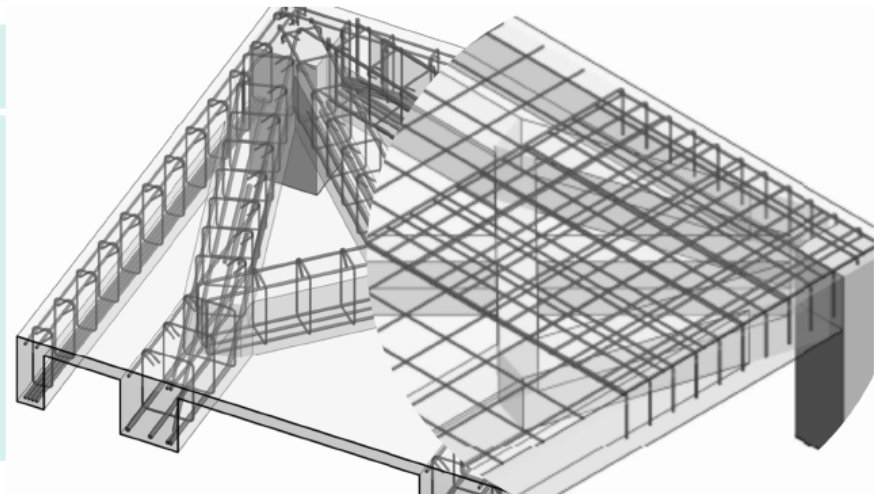
- ▶ **Structural:** TO ribs + PT attack the real driver: **deflection/cracking**.
- ▶ **Material + environmental:** LC3 cuts CO₂ in the bulk ribs; eco-UHPFRC keeps cracks tight.

Section sketch

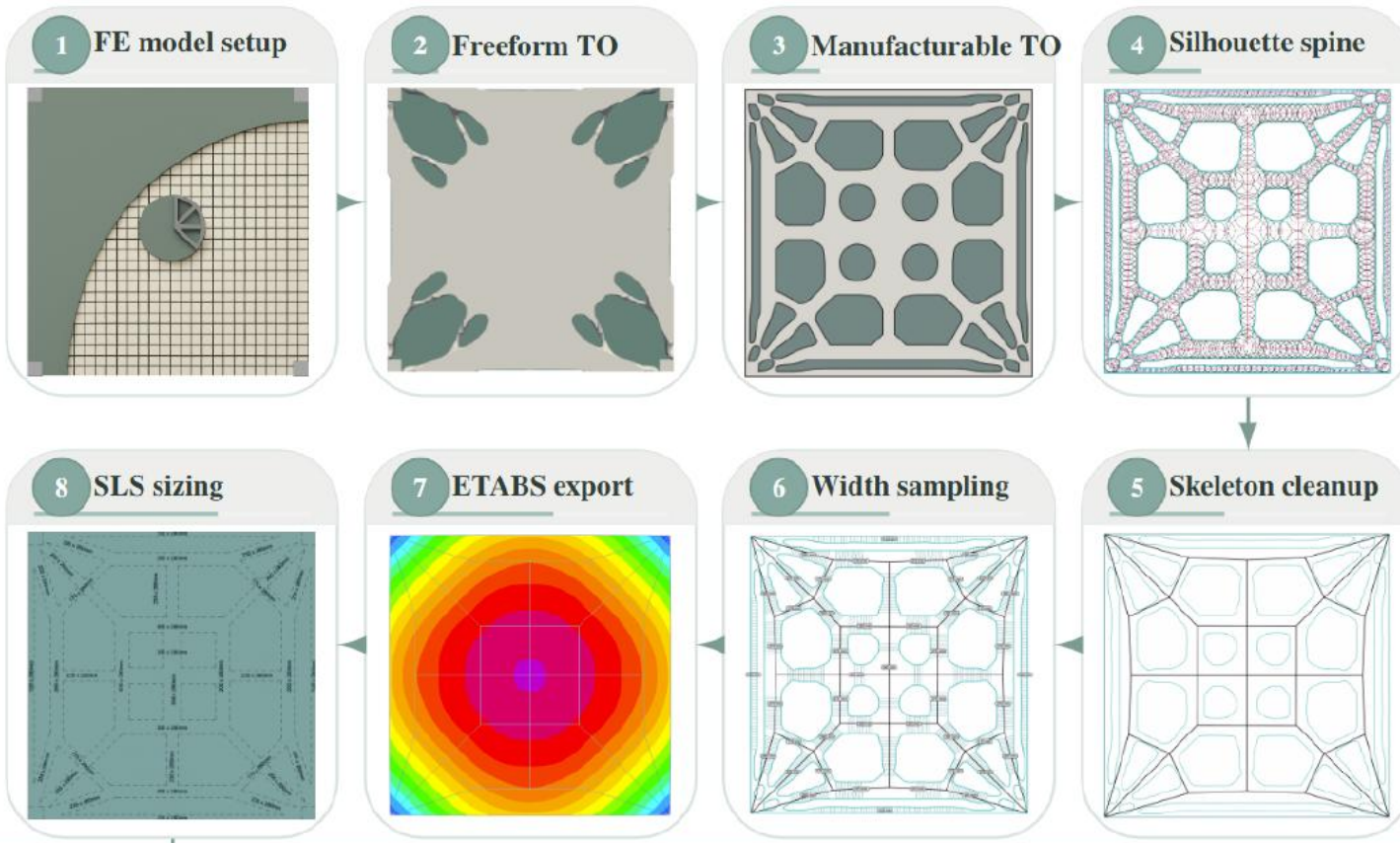
Eco-UHPFRC topping (t_f)



LC3 ribs + PT ducts in main corridors



End-to-end pipeline, then add PT + eco-materials as a *post-processing layer*



In-loop (optimisation):

- ▶ KS-aggregated SLS deflection limit d_{\max} .
- ▶ Manufacturability grammar: t_{\min} , g_{\min} , ϕ_{\max} + extrusion.

Post-processing (our add-on):

- ▶ Skeletonise ribs → centreline graph.
- ▶ Route tendons + map materials + A1–A3 calculator.

Assumed building bay

- ▶ **Interior bay, continuous action:** $L_x = L_y = 8.0$ m (representative).
- ▶ Loads: $g_{k,SDL} = 3$ kN/m², $q_k = 5$ kN/m² + self-weight.
- ▶ SLS limit: $d_{max} = \frac{L}{250 \gamma_{lt}}$, $\gamma_{lt} = 3 \Rightarrow d_{max} \approx 10.7$ mm.

Geometry knobs (manufacturable by construction)

Knob	Chosen value (start point)
Topping thickness t_f	50 mm (eco-UHPFRC)
Rib min thickness t_{min}	120 mm
Min clear gap g_{min}	450 mm
Max solid zone ϕ_{max}	300 mm

Benchmark logic

- ▶ Compare against two **deflection-matched** baselines:
 - ▶ solid flat plate
 - ▶ conventional waffle / ribbed slab (ERS)
- ▶ Report: concrete (t/m²), steel (kg/m²), and A1–A3 CO₂.

Deliverable: a buildable rib centre-line graph + tendon paths + bar template + carbon dashboard.

Anchor results + why this combo

- ▶ **Simply supported:** ~42% less concrete, ~23% less steel, ~39% less A1–A3 CO₂ vs equal-deflection solid.

Why each ingredient belongs:

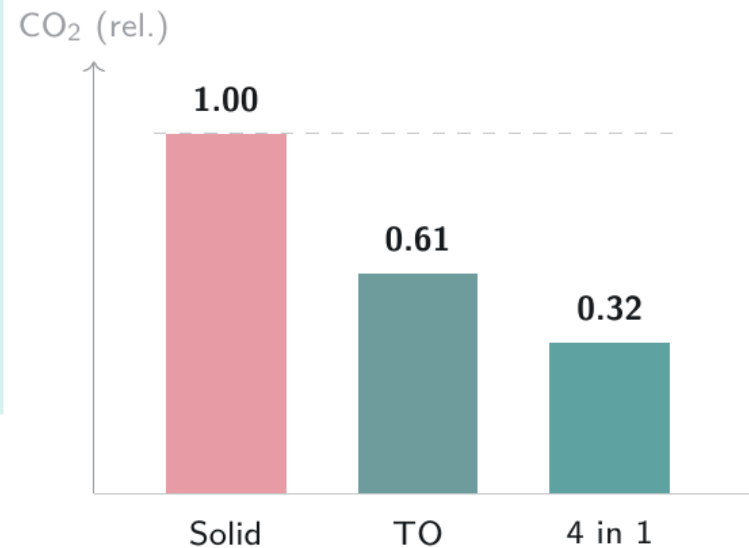
LC3 ribs *Material:* low-clinker binder in the bulk volume. *Environmental:* lower CO₂ per m³.

PT tendons *Structural:* targets SLS (deflection/cracking) directly. *Construction:* tendon “highways” follow straight ribs.

Eco-UHPFRC *Structural:* tight cracks + durability in a thin layer. *System:* fixed topping keeps optimisation + detailing clean.



Scenario: current research ~39% A1–A3 reduction by geometry; add LC3 (up to ~40% lower cement emissions factor) → ~68% vs solid (EPD-dependent).



Research plan (headlines)

1. **Bay setup + baselines:** solid + ERS tuned to the same SLS deflection.
2. **MC-Extruded TO:** serviceability + buildability in-loop; extract rib graph.
3. **PT + eco-materials:** tendon routing along main ribs; LC3 ribs + eco-UHPFRC topping.
4. **Validation + dashboard:** small prototype (deflection/cracks) + A1–A3 roll-up from quantities.

Resources

Tools	FE+TO scripts (Python/MATLAB) + EC2.
Lab/kits	Mixer, curing, actuator+LVDTs; PT jack+anchors.
Team+budget	3 PhD + 1 lab engineer + 2 technician; 360–450k CHF.

4-year schedule

Baselines + bay FE
TO + manufacturability
PT routing + eco-materials
Prototype + dashboard

Expected outputs / benefits

- ▶ A repeatable TO+PT workflow with buildability knobs.
- ▶ A rib+tendon layout that is **code-checkable** and **carbon-auditable**.

Experts: Guillaume Habert; Walter Kaufmann; Emmanuel Denarié; Oren L. Amir; Luigi Coppola; Ahmad Majdoub.